A Study on the Flexural Strength Capacity of Wall Stud Assembly

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Sixteenth International Specialty Conference on Cold-Formed Steel Structures
Orlando, Florida USA, October 17-18, 2002

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ABSTRACT

An investigation on the ultimate and service load capacity of cold-formed steel lipped C-section studs for the wall system is presented. An experimental research has been carried out to study the structural behavior of stud assembly subjected to lateral loads. Each test specimen consisted of three or four lipped C-section studs and two C-section tracks which restrain both ends of wall studs from rotation. The effects of main parameters, such as perforation on the web, space of bridge channel and special clip to fix the bridge channel and to sustain the distance between lips, were studied in the experimental work. The effect of gypsum board and ply wood attached to tension flanges was also investigated. The test strength capacity was compared with the nominal flexural strength and lateral buckling strength based on the AISI Specifications (1996).

Introduction

The strength capacity of the wall composed of lipped C-section stud and bracing (called bridge channel) is decided mainly by the strength of stud member itself and the unsupported length of stud members decided by the space of bridge channels attached. The structural behavior of cold-formed steel lipped C-sections subjected to bending and compression is significantly influenced by the section size and space of the utility holes on the web of sections and bracing condition of the members. In Korea, the thickness of C-section for the non-load-bearing wall is strictly limited to 0.8mm or over and bridge channel must be used for safety in the Korean Standards. In Korea two different bracing techniques are generally used: a channel passing through the web at the mid-span of C-section, commonly called a bridge channel and gypsum wall board attached to flanges of C-sections. In this research, the effect of the hole and special spacer for fixing the bridge channel and the gypsum board on the strength of stud and stud assembly was focused on.

The bridge channel is generally attached to the stud by using special clip as shown in Fig. 1. In Korea, an experimental study focused on the space of holes for passing the bridge channel through the web panel and the special clip fixing the bridge channel. The effect of the hole and the clip on the strength capacity of C-section under uniform compression was studied at first. The same effect on the flexural member was studied and the effect of the bridge channel system, gypsum board and ply wood on the flexural strength capacity of the stud was also investigated. The variation of the strength capacity according to the space between studs on center was also investigated. The test

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strength was compared with the nominal and stability strength calculated by the AISI Specifications (1996).

Material Properties

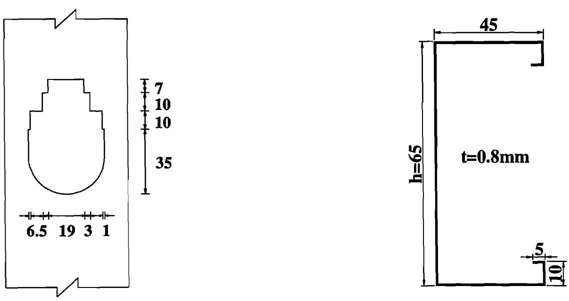
The mechanical properties of C-sections used (nominal yield stress F_y=240MPa) were measured by the tensile coupon test in accordance with Korean Standard (KS) B0801 (equivalent to ASTM A370). Four coupons were taken from the center of the web plate and the edge between flange and web in the longitudinal direction of the lipped C-sections of 0.6mm thickness. All coupons were tested in a 250 kN capacity UTM with friction grips and strains were measured with using strain gagues and extensometer. The average values of tensile coupon test are summarized in Table 1.

Table 1 Measured Material Properties

Yield stress F_y (MPa)	Ultimate tensile stress F_u (MPa)	Young's Modulus (MPa)	F_u / F_y	ε (%)
289	339	196450	0.854	50

Compression Test

Compression Test for the lipped channel sections (shown in Fig. 1) of 1200mm length subjected to uniform compression was carried out to investigate the effect of perforation and special clip on the buckling stress and mode. The hole was perforated to pass the bridge channel through the web of channel and the special clip was developed to fix the bridge channel tightly. The return lip was added for connection of the special clip and studs. The distance on center of perforations and clips was ranged from 600mm to 900mm.



(a) Hole on the web (b) Cross section

Fig. 1 Test Section Geometry (unit: mm)

Test results are given in Table 2 and Fig. 2. The maximum compression load was decreased with 6% and 14% according to the perforation distance respectively in comparison with the load of unperforated section. However, the clip had little effect on the buckling stress of the section. In addition, there was not found of any possibility for the change of buckling mode.

Table 2 Dimension of Sections and Test Results

Specimens	Length (mm)	Perforation Space (mm)	Clip Space (mm)	Max. Compression Load (kN)	Ratio to WS65-1200-0
WS65-1200-0	1200	-	-	26.48	1.0
WS65-1200-900	1200	900	-	24.91	0.94
WS65-1200-600	1200	600	-	22.65	0.86
WS65-1200-600-S	1200	600	600	23.54	0.89
WS65-1200-900-S	1200	900	900	24.42	0.92

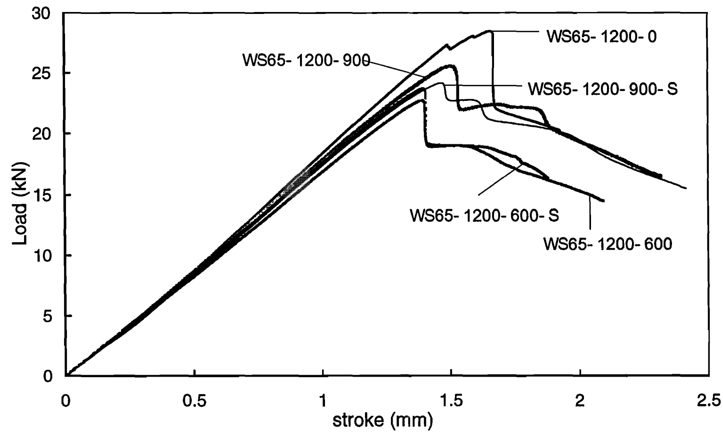


Fig. 2 Compression Test Results

Flexural Test Specimens and Test Set-up

The measured dimensions of test specimens are given in Table 3. The connection of bridge channel and stud sections with special clip are shown in Fig. 3. Each test specimen consisted of four lipped C-section studs and two C-section tracks to restrain both ends of studs from rotation as shown in Fig. 4(a). The track sections were connected to the lipped C-section studs by using self-drilling screw fasteners. Test sections were grouped into mainly four categories: group A indicates that there are no bridge channel used, the section has perforations on the web for group B, E designates that bridge channels are used and gypsum board or ply wood are attached in F group. In addition, two specimens of C-1 and D-1 that had clips inserted with/without perforations were selected to find out the effects of special clips and perforations on the ultimate flexural strength of studs.

The test specimens were simply supported by placing a roller at each support as shown in Fig.

4(b). Two point loads were applied to each C-section using UTM and spreader beams to create 1/4 point loading condition as shown Fig. 4(b) and Fig. 5. The displacement of the stud assembly was measured by three linear varying displacement transducers (LVDT) which were placed at the center of mid span and under spreader beams.

Table 3 Measured Dimensions of Flexural Test Specimens

Specimens	Dimensions of Stud			Perforation			Bridge Channel	Clip		
	h (mm)	t (mm)	L (mm)	Edge distance (mm)	Diameter (mm)	Space (mm)		Edge distance (mm)	Space (mm)	Number
A-1	65	0.8	3200	-	-	-	-	-	-	-
B-1	65	0.8	3200	400	40	600	-	-	-	-
B-2	65	0.8	3200	400	40	1200	-	-	-	-
C-1	65	0.8	3200	-	-	-	-	400	600	5
D-1	65	0.8	3200	400	40	600	-	400	600	5
E-1	65	0.8	3200	400	40	1200	O	400	600	5
E-1	65	0.8	3200	400	40	1200	O	400	600	5
E-1	65	0.8	3200	400	40	1200	O	400	600	5
F-1	65	0.8	3200	Gypsum board (t=12.5mm) 1 sheet						
F-2	65	0.8	3200	Gypsum board (t=12.5mm) 2 sheets						
F-3	65	0.8	3200	Ply wood (t=10mm)						

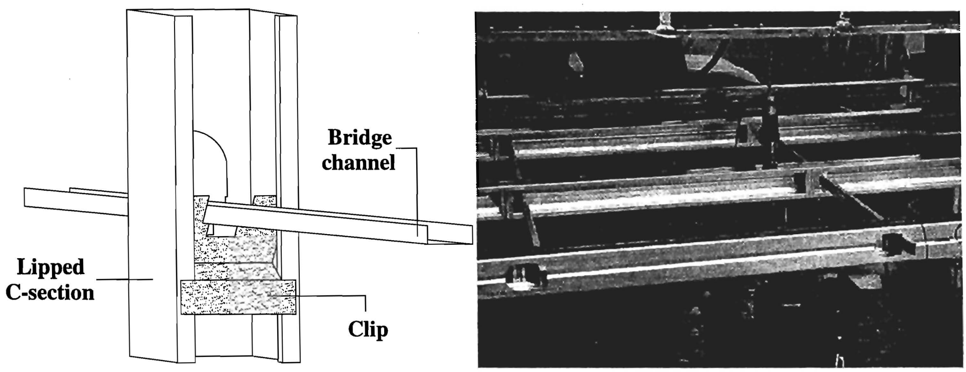
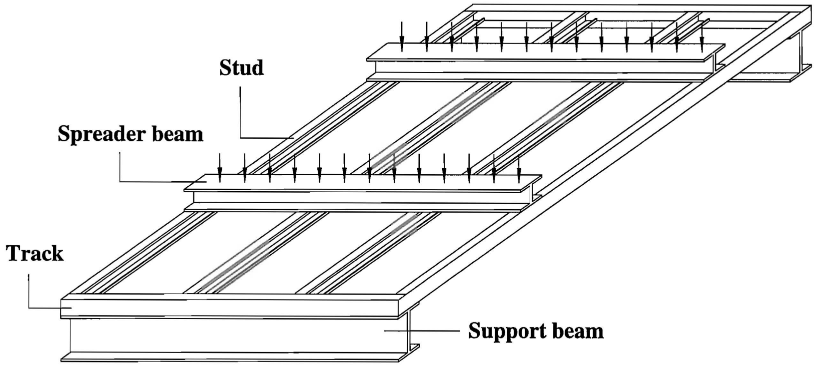
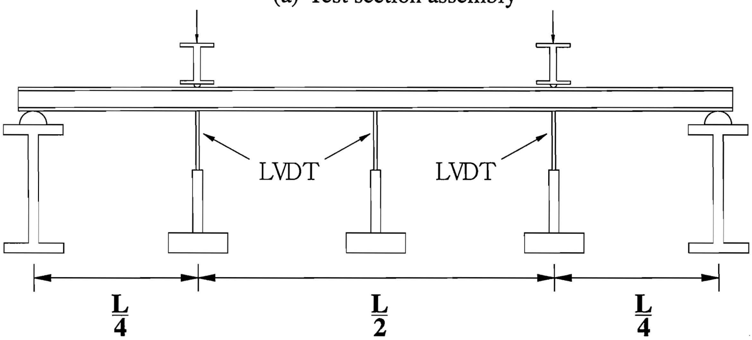


Fig. 3 Attachment of Bridge Channel with Special Clip



(a) Test section assembly



(b) Test frame elevation

Fig. 4 Test Setup Detail

Fig. 5 Flexural Test Set-Up

Test Results

As the load was increased, the test specimen deflected vertically at the lower load stage until the flexural-torsional buckling occurred near the theoretical buckling load. In the case of thin sections, local buckling was observed before global buckling occurred. The buckled shapes of stud are shown in Fig. 6 and test results are summarized in Table 4. The nominal load R_n and stability load R_l were calculated according to the AISI specifications (1996) and were compared with the flexural test results of wall stud assembly in Table 4.

Table 4 Comparison of Test Strength with Design Strength

Specimens	R_{def} (kN)			R_d (kN)		M_u (kN·m)	R_u (kN)	Compare with A-1	
	L/120	L/240	L/300	R_n (kN)	R_l (kN)			M_u (/A-1)	L/120 (/A-1)
A-1	3.00	1.66	1.26	6.25	3.93	2.38	5.95	1.00	1.00
B-1	3.02	1.56	1.27	6.25	3.93	1.82	4.56	0.77	1.01
B-2	3.05	1.68	1.19	6.25	3.93	1.86	4.68	0.79	1.02
C-1	3.24	1.64	1.32	6.25	3.93	2.40	6.02	1.01	1.08
D-1	2.72	1.44	1.22	6.25	3.93	1.66	4.14	0.70	1.08
E-1	5.25	2.31	1.75	6.25	5.87	2.63	6.57	1.10	1.75
E-2	5.67	2.62	1.98	6.25	5.87	2.66	6.64	1.12	1.89
E-3	6.04	2.86	2.28	6.25	6.16	2.96	7.41	1.25	2.01
F-1	5.95	2.38	1.71	6.25	5.89	3.62	9.04	1.52	1.98
F-2	7.08	3.38	2.58	6.25	5.89	4.47	11.18	1.88	2.36
F-3	6.24	2.55	1.89	6.25	5.89	4.41	11.03	1.85	2.08

R_{def} = load at which indicated deflection occurred; R_d = design load; R_n = nominal load; R_l = flexural-torsional load; M_u = failure moment; R_u = failure load

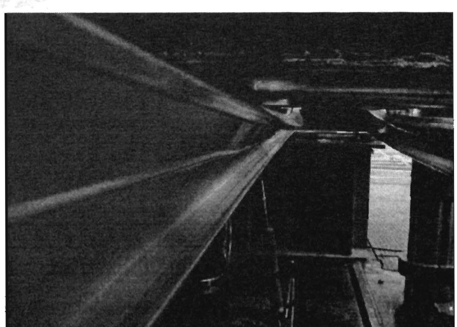


Fig. 6 Buckled Shape of Test Sections

- Effect of Perforation and Clip

To have the bridge channel pass through the web of studs, the perforation on the web is inevitable. Comparison of A-1 and B-1 and B-2 showed that the effect of perforation on the flexural strength was insignificant to the extent of serviceability limit. However, it caused that the failure load was decreased by about 20%. The distance of perforations was founded to have little effect on the flexural strength of studs. The results of C-1 and D-1 showed the effect of special clip on the failure load was also negligible as shown in Fig. 7.

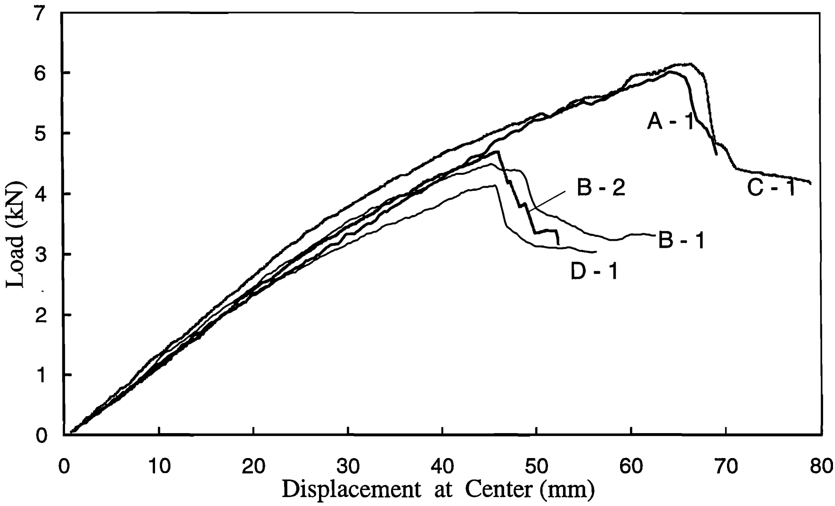


Fig. 7 Effect of Perforations and Clip

- Effect of Bridge Channel

As shown in Fig. 8 and Table 4, in case of the specimens which have bridge channel attached with 600mm and 1200mm interval, failure load increased from 10% to 25% respectively. However, the load with which the deflection L/120 occurred, was increased by 75% and 100% respectively, being compared with A-1. These results were caused by attachment of bridge channels which could restrain flexural-torsional buckling of stud properly. Consequently, it could be concluded that the attachment of bridge channel attached with the specially designed clips could improve the flexural strength capacity of wall stud assembly effectively. From the experimental results, the difference in flexural strength of the stud which was obtained with 600mm and 1200mm space, was approximately 10%. Hence the interval of 1200mm for the bridge channel could be adopted for practical use. The special clip could produce enough restraining strength for support of the flexural member. The special clip to fix the bridge channel and additionally to provide the restraint against distortion of the section when the gypsum board is attached on the tension flange of the stud, had shown little effect on the strength of studs.

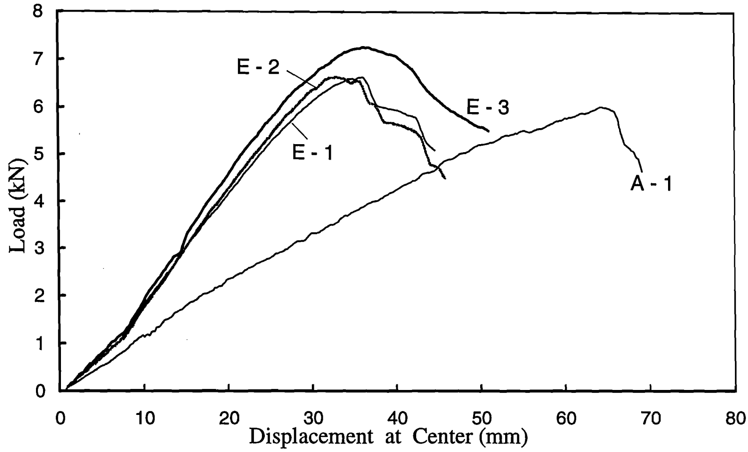


Fig. 8 Effect of Bridge Channel

- Effect of Gypsum Board and Ply Wood

The gypsum board and ply wood were attached to the tension flange of studs by self-drilling screw fasteners with 10 cm interval. The results of F-1, F-2 and F-3 in Table 3 and Fig. 9 show that gypsum board and ply wood have increased the flexural strength significantly. The attachment of a sheet of gypsum board increased the flexural strength by 52% which might include the composite effects also. However, it is concluded that the gypsum board can be used more effectively than bridge channel to increase the flexural strength capacity. Consequently, the bridge channel need not be used to enhance the flexural strength of stud sections for non-load bearing wall attached with gypsum board properly.

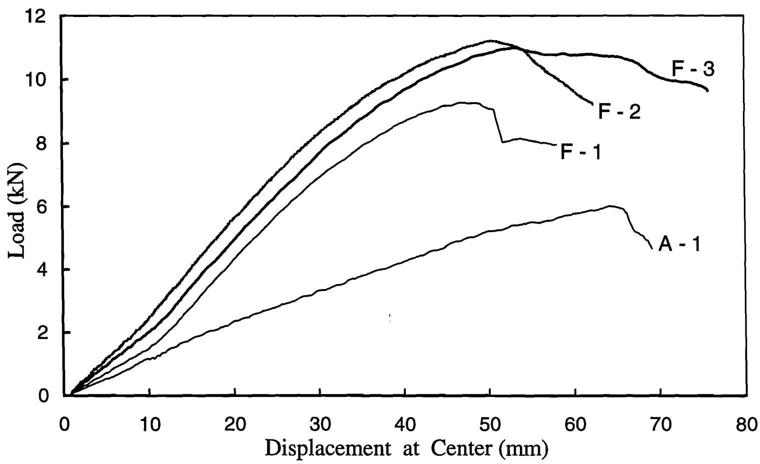


Fig. 9 Effect of Gypsum Board and Ply wood

Concluding Remarks

From the test results and comparison with AISI Specifications (1996), the connection method to fix bridge channel to studs with using special clips has been found to give restraint condition properly without loss of flexural strength due to perforations. The perforation on the web of stud sections decrease the compression and flexural strength by 10%-20% and the special clip has little strengthening effect on compressive and flexural strength of the stud. The gypsum board and ply wood attached to the tension flange of stud sections could significantly increase the flexural strength of the stud. The composite action of stud and gypsum board should be studied further and be included in the design of wall system. For the non-load bearing wall, if a gypsum board with a certain thickness (t=12.5mm) is attached properly, there could be no need using bridge channels or other secondary members to enhance the flexural strength of stud sections and walls.

References

1. G. J. Hancock, Design of Cold-Formed Steel Structures (To Australian/New Zealand Standard AS/NZS 4600:1996), 3rd Edition, Australian Institute of Steel Construction, 1996.
2. G. J. Hancock, T. M. Murray and D. S. Ellifritt, Cold-Formed Steel Structures to AISI Specification, 1st Edition, Marcel Dekker, Inc., New York, 2001.
3. American Iron and Steel Institute (1996), "Specification for the Design of Cold-Formed Steel Structural Members," Washington, DC, 1996.
4. Cold-Formed Steel Design Manual, 1996 Edition, American Iron and Steel Institute, 1996.
5. B. Beshara and R. A. LaBoube, "Later Bracing Connections for C-Section Subjected to Bending", Proceedings, 15th International Specialty Conference on Cold-Formed Steel Structures, ST. Louis, Missouri USA, 2000.
6. RIST Technical Report (2001), Research Institute for Industrial Science and Technology, 2001.